SEMESTER-2 (Period-VI)

TOPIC 6

Light

P11CH6

6.1. LIGHT

Light *is that form of energy* (*optical energy*), *which helps us in seeing objects from which it comes or from which it is reflected e.g.,* sun gives us light and hence we can see the sun.

Light *may also be defined as that form of energy which produces in us the sensation of vision* (*sight*).

(We do **not see light** because light itself is not visible, since **no energy is visible**.)

Light falling on the objects, returns from them and then falls on our eyes, which makes objects visible. **Our eye is a natural optical instrument.**

6.2. SOURCES OF LIGHT

Objects from which the light comes out are called ***sources of light****.* Some sources are **natural** while many others are **man–made**. For us on the earth, **Sun is the most important natural source of light.** Electric lamps, oil lamps and candles are some of the man made sources of light.

Objects which are visible through the light emitted by them, are called ***luminous sources.*** Sun, stars, bulbs, candles, etc. are luminous objects.

There are certain objects which do not emit their own light but still we can see them *e.g.,* table, chair, etc. This is due to the reason that when light from some source is incident on these objects, then it gets reflected or scattered. This reflected or scattered light enters our eyes and we are able to see these objects. *These objects, which do not emit* *their own light but become visible due to the light reflected or scattered by them are called* ***non-luminous objects.*** Hence, we can say that **light is the form of energy which produces in us the sensation of vision.**

6.3. NATURE OF LIGHT

Depending on the type of observation and level of understanding, there are two theories about the nature of light *i.e.*, **wave theory of light and particle theory of light**.

(*i*) **Wave theory of light.** According to this theory, light travels from the source in the form of a wave. The waves are found to be **transverse electromagnetic waves**. *These waves do not require any material medium for their* **propagation**.

The **speed of these waves is 3×10^8 m s^{-1}** in vacuum and slightly less in air. The speed of light is represented by the symbol *c*. Its actual value is, c = 299,792,458 m s^{-1}.

The wavelength of visible light ranges from 4×10^{-7} m to 8×10^{-7} m and is very small as compared to the size of usual objects. *Light waves travel (propagate) from one point (source) to other in a straight line, called the* ***ray of light***. The rays are taken to be perpendicular to **wave front** (front of the wave).

(*ii*) **Particle theory of light.** According to this theory, *light is made up of some elementry particles, called* **photons** *which travel in straight line with very high speed.*

Photons have **only energy** and **no rest mass** and **no charge.**

This particle nature has been used to explain a new additional phenomenon, called photoelectric effect.

6.4. PHOTON ENERGY AND COLOUR OF LIGHT

White light consists of **seven** colours namely **V**iolet, **I**ndigo, **B**lue, **G**reen, **Y**ellow, **O**range and **R**ed (remembered by the word **VIBGYOR**).

Photon of **red light has minimum frequency** (minimum energy, $E = h\nu$) and the **red light has maximum wavelength.**

Photon of violet **light has maximum frequency** (maximum energy, $E = h\nu$) and the **violet light has minimum wavelength**.

Thus we can say that, red light photons have minimum energy *i.e.*, **red light is least energetic** and violet light photons have maximum energy *i.e.*, **violet light is most energetic.**

6.5. DUAL NATURE OF LIGHT

It has been found that some phenomena like diffraction, interference and polarisation of light can be explained only if light is considered to be of wave nature whereas some other phenomena like reflection of light, refraction of light, photoelectric effect cannot be explained by wave nature of light but can be explained only if light is considered to be made up of particles.

Hence we can say that *light has a dual nature, particle nature as well as wave nature.*

According to the particle nature, light consists of photons having frequency ν (nu) and energy, $E = h\nu$ (where h is Planck's constant).

According to the wave nature, light consists of waves having wavelength λ (lamda) and velocity, $c = \nu\lambda$.

Combining both relations, we get, energy,

$$E = h\nu = \frac{hc}{\lambda} \quad i.e., \; E \propto \frac{1}{\lambda}$$

6.6. RAY AND BEAM OF LIGHT

1. **Ray of Light: A *ray of light is a straight line along which light travels*.** In Fig. 6.1, OP represents a ray of light.

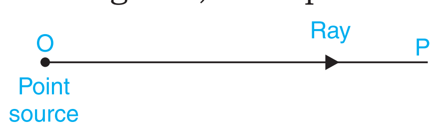


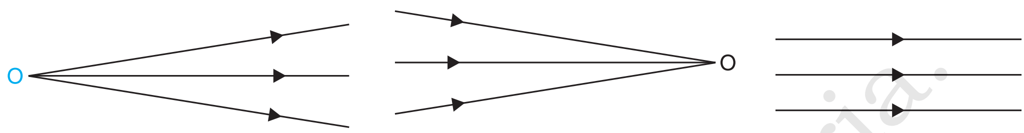
Fig. 6.1. Ray of light.

2. **Beam of light:** A bundle of rays associated with a point source, form a beam of light.

   It is shown in Fig. 6.2.

If the rays of a beam come out of the point source (O), then beam is **diverging** [Fig. 6.2(*a*)].

If the rays of a beam meet at a point (O), then beam is **converging** [Fig. 6.2(*b*)].



(a) A diverging beam (b) A converging beam (c) A parallel beam

Fig. 6.2. Beam of light.

A beam of light, in which all the rays are parallel to each other, is called **parallel beam** of light.

6.7. OPTICAL MEDIUM

*Substance, surrounding a source of light through which light travels, is called **optical medium** or **simply medium.*** A medium can be : transparent, opaque or translucent.

(*i*) **Transparent medium:** Medium through which light can completely pass, is called a transparent medium.
Examples: Air, water, glass.

(*ii*) **Opaque medium:** Medium through which no light can pass, is called an opaque medium.
Examples: Wood, wall, metals.

(*iii*) **Translucent medium:** Medium through which light passes only partially, is called a translucent medium.
Examples: Tracing paper, oil-soaked paper.

6.8. PROPAGATION OF LIGHT

Light travels in a straight line from a source as long as it remains in one medium and is not obstructed by any object. This mode of propagation of light is called **rectilinear propagation**. Activity 6.1 demonstrates that light travels in a straight line.

ACTIVITY 6.1

To Demonstrate that Light Travels in a Straight Line

Materials Required

Three rectangular pieces of cardboard, a candle, and a lighter

Procedure

1. Take three rectangular pieces of cardboard.
2. Make holes in each of them in the centre such that all the holes are at exactly the same horizontal level.
3. Make the cardboard stand straight and parallel on a table using wooden supports.
4. Make sure that the holes in all the three cardboard pieces are aligned.
5. Light the candle and keep it on the table with its flame at the level of the hole in the first cardboard.
6. Now keep your eye in front of the third cardboard and adjust the cardboards such that you can see the candle flame through the holes [Fig. 6.3 (a)].

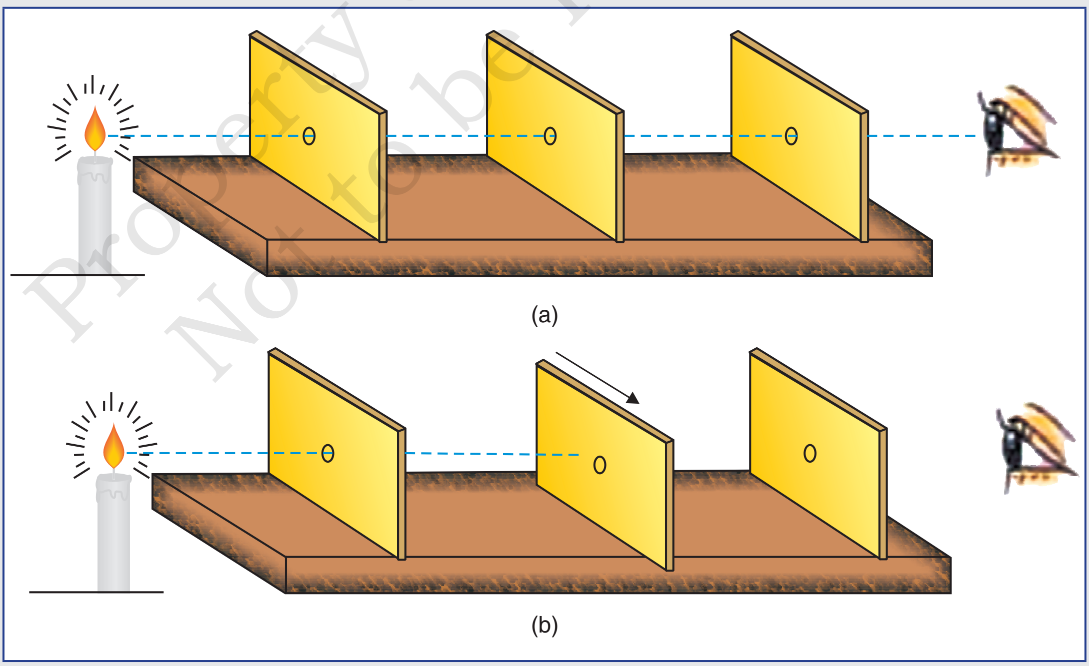


Fig. 6.3. Experiment to show that light travels in a straight line

7. Move one of the cardboards slightly to misalign its hole to the others and observe.
8. What do you observe [Fig. 6.3 (b)]?

Observation

You will observe that the flame can only be seen when the holes are exactly in a straight line. If you disturb one of the cardboards, you will no longer be able to see the flame. This activity clearly proves that light travels in a straight line.

6.9. REFLECTION AND REFRACTION OF LIGHT

Reflection

You can see an object only when light falls on it. When light falls on a surface, it bounces off the surface and strike our eyes. It makes us see the things. *The bouncing back of light rays from a surface is called* ***reflection***.

Refraction

Refraction *is the bending of light as it crosses the interface between two different transparent media.*

6.10. TYPES OF REFLECTION

There are two types of reflection, known as Regular and Diffused reflection.

ACTIVITY 6.2

Imagine that parallel rays are incident on an irregular surface as shown in Fig. 6.4. The laws of reflection are valid at each point of the surface. Use these laws to construct reflected rays at various points. Are they parallel to one another? You will find that these rays are reflected in different directions (Fig. 6.5).

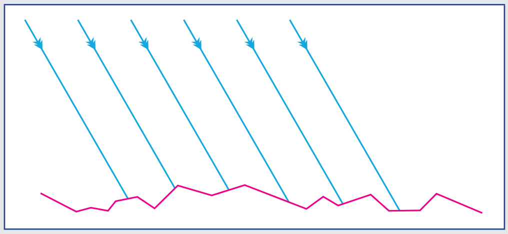


Fig. 6.4. Parallel rays incident on an irregular surface

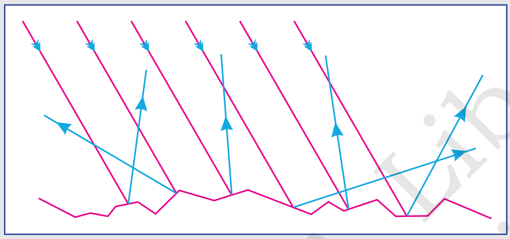


Fig. 6.5. Rays reflected from irregular surface

When all the parallel rays reflected from a plane surface are not parallel, the reflection is known as **diffused** or **irregular** reflection. Remember that the diffused reflection is not due to the failure of the laws of reflection. It is caused by the irregularities in the reflecting surface, like that of a cardboard.

On the other hand reflection from a smooth surface like that of a mirror is called **regular reflection** (Fig. 6.6). Images are formed by regular reflection.

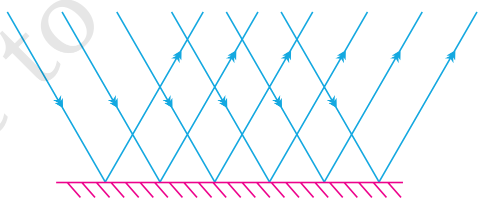


Fig. 6.6. Regular reflection

6.11. FORMATION OF SHADOWS

We now know that light travels in a straight line. So, an opaque object blocks the light falling on it. This creates an area of darkness on the side of the object away from light. This area of darkness is called the **shadow** of the object.

The following three things are required for a shadow to form (Fig. 6.7):

- a source of light;
- an opaque object; and
- a screen or surface behind the object.

Fig. 6.7. Formation of shadow

A shadow cannot form if any of these is absent. This explains why we cannot see a shadow in the dark. It is only when light rays are obstructed by an opaque object that we get a shadow of the object. Activity 6.3 will make us understand the formation of shadow and its characteristics.

ACTIVITY 6.3

To Obtain a Shadow and Study its Characteristics

Materials Required

A torch, a few small opaque objects of different shapes and sizes, and a white screen (a piece of cardboard covered with white paper).

Procedure

1. Turn on the torch and place any opaque object in front of it.
2. Hold the screen on the other side of the object to get the shadow.
3. Ask your friend to trace out the outline of the shadow on the screen.
4. Now, keeping the positions of the torch and the screen intact, move the object closer to the torch. What do you see?
5. Note the size of the shadow.
6. Repeat steps 1 to 5 for different objects.
7. Does the colour of the shadow change with size or for various different objects?

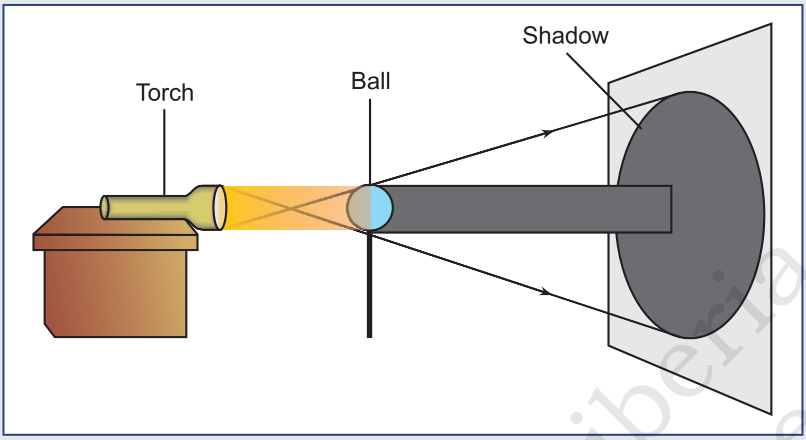


Fig. 6.8. Demonstration of formation of shadow

Observation

The shadow becomes bigger when the object is moved closer to the torch, and smaller when it is moved closer to the screen. The colour of the shadow is always black.

Characteristics of a Shadow

A shadow has the following three characteristics:

1. It is always black, regardless of the colour of the object used to make the shadow.
2. It only shows the shape or outline of the object and not the details.
3. The size of a shadow varies. It depends on the distance between the object and the source of light, and the distance between the object and the screen.

Identification of Umbra and Penumbra

If the light source is a point, then all objects will have one kind of shadow behind them. But if the light source is a sphere, then every object has behind it a core shadow known as **umbra** and a sort of side-way shadow known as **penumbra**. Similarly, the distant light source forms penumbra and umbra irrespective of its shape.

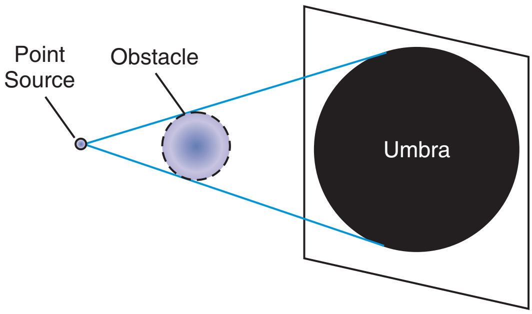


Fig. 6.9. Formation of umbra

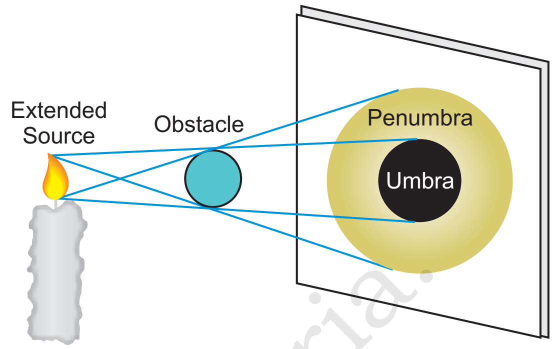


Fig. 6.10. Formation of umbra and penumbra

6.12. FORMATION OF ECLIPSES

Eclipse is the blocking of light from the sun by the interference of the moon or earth. There are two types of eclipse.

(*a*) Solar eclipse

(*b*) Lunar eclipse

Solar Eclipse

Solar eclipse is the eclipse of the sun. It occurs when the moon passes between the sun and the earth. The shadow of the moon may completely block the sun. This is called **total solar eclipse.** And when only a portion of the sun is out of view, it is called **partial solar eclipse**.

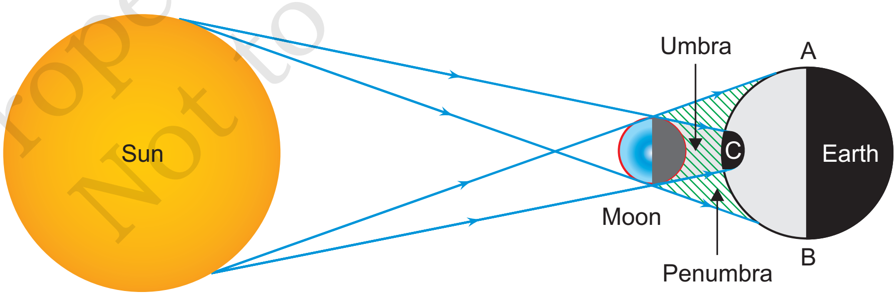


Fig. 6.11. Solar eclipse.

Lunar Eclipse

Lunar eclipse (eclipse of the moon) occurs when the earth passes between the sun and the moon. The shadow of the earth falls on the moon, blocking its view, partially or totally.

Umbra: It is the darkest part of the shadow. Here all the light from the source is blocked.

Penumbra: It is the region where the shadow is partial.

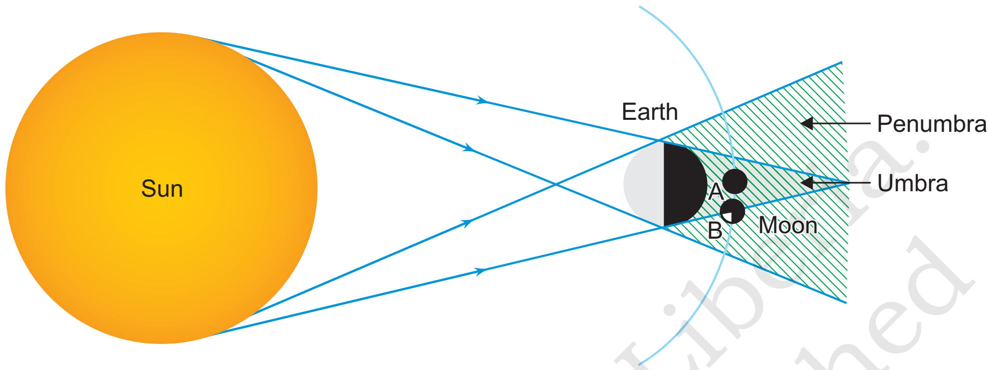


Fig. 6.12. Lunar eclipse

When the whole sheet of paper is spread on the table, it represents one plane. The incident ray, the normal at the point of incidence and the reflected ray are all in this plane. When you bend the paper you create a plane different from the plane in which the incident ray and the normal lie. Then you do not see the reflected ray. What does it indicate? It indicates that **the incident ray, the normal at the point of incidence and the reflected ray all lie in the same plane**. This is another **law of reflection**.

Thus, the law of reflection states that

(*i*) the angle of incidence is always equal to the angle of reflection.

(*ii*) the incident ray, the normal at the point of incidence and the reflected ray all lie in the same plane.

6.13. PINHOLE CAMERA IMAGE FORMATION AND MAGNIFICATION

A pinhole camera consists of a light proof box with a pinhole on one end and a screen of tracing paper at the other end. It has no lens. The image is formed by light travelling in straight line from an object to the screen.

A common use of the pinhole camera is to capture the movement of the sun over a long period of time. It is popular for observing solar eclipses.

Operation of the Pinhole Camera

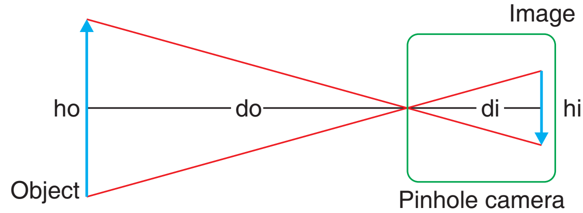


Fig. 6.13

Aim the camera at a bright object in a darkened room. You will see an upside down image on the tracing paper. The upside down image is formed because light rays travel in a straight line. The light rays from the top of the object travel through the pinhole and strike the bottom of the screen of pinhole camera. The light rays from the bottom of the object travel through pinhole and strike the top of the screen of the pinhole camera, thus forming the upside down image.

If a line is drawn through the pinhole and perpendicular to both the image and the object, it can be shown by similar triangles that:

$$\text{Magnification } m = \frac{\text{height of image}}{\text{height of object}} = \frac{\text{distance of image}}{\text{distance of object}}$$

$$m = \frac{hi}{ho} = \frac{di}{do}$$

Example 1. *What is the height of an image if an object 8.0 cm high is 125 cm from a pinhole camera that is 21 cm long?*

Solution.

$$\frac{hi}{ho} = \frac{di}{do}$$

$$hi = \frac{diho}{do}$$

$$hi = \frac{21 \cancel{cm} \times 8.0 \text{ cm}}{125 \cancel{cm}}$$

$$\boxed{hi = 1.3 \text{ cm}}$$

What is the magnification?

$$m = \frac{di}{do}$$

$$m = \frac{21 \cancel{cm}}{125 \cancel{cm}}$$

$$\boxed{m = 0.17}$$

Example 2. *What is the actual size of an object if the magnification is 0.20 and the image is 3.5 cm high?*

Solution.

$$m = \frac{hi}{ho}$$

$$0.20 = \frac{3.5\text{ cm}}{ho}$$

$$ho = \frac{3.5}{0.20}\text{ cm} = 17.5\text{ cm}$$

6.14. REFLECTION OF LIGHT

When light is incident on the surface of an object then it may be reflected, absorbed or transmitted.

When whole of the light, incident on the surface of an object, is absorbed by the object then object appears black. Our hairs appear black because they absorb most of the light incident on them.

If the object allows the incident light to pass through it then object is said to be transparent *e.g.,* sheet of ordinary glass. *When light passes through a transparent medium, it bends from its path and this phenomenon is called* ***refraction of light.***

If light falls on an opaque polished smooth surface (medium), then it returns back in the same medium.

For example, a polished silver mirror reflects back most of the light incident on it.

This phenomenon of sending back of rays of light in the same medium when they are incident on a smooth polished surface is called ***reflection of light.***

Some objects reflect more light and some objects reflect less light. Objects with polished shining surfaces reflect more light than the object having dull surfaces. **Silver metal is the best reflector of light.**

6.15. REFLECTION OF LIGHT FROM A PLANE POLISHED SURFACE

Since silver metal is the best reflector of light, hence ordinary mirrors are made by depositing a very thin layer of silver on one side of the plane glass sheet. **Then thin silver layer is coated with red paint, so as to protect the silver coating.** Reflection of light from a plane mirror takes place at the interface of glass and silver.

In our future discussion and while making diagram, a plane mirror is represented by a straight line with a number of oblique lines on its back side.

In Fig. 6.14, XY is section of a plane polished surface mirror. A ray of light PO strikes the surface at O and is returned back along OQ. An arrow on PO and OQ gives us the direction of propagation of ray of light.

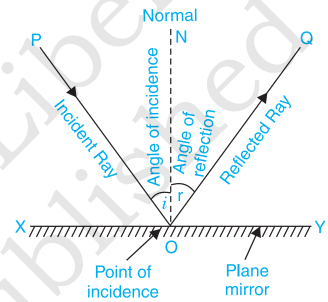


Fig. 6.14. Reflection of light from a plane polished surface.

The returning back of the light in same medium is called ***reflection.***

Some important terms associated with the reflection from a plane polished surface are given below:

(*i*) **Reflecting surface:** The surface from which the light is reflected, is called the reflecting surface. In diagram, *XY* is the reflecting surface, (**Actually** XY is the section of a reflecting surface, made by the plane of the book page which is perpendicular to it). Silver metal is one of the best reflectors of light.

(*ii*) **Point of incidence:** The point on the reflecting surface at which a ray of light strikes, is called the point of incidence. In Fig. 6.14, O is the point of incidence.

(*iii*) **Normal:** Normal is a line, perpendicular to the reflecting surface, at the point of incidence. In Fig. 6.14, NO is the normal.

(*iv*) **Incident ray:** The ray of light which strikes the reflecting surface at the point of incidence is called the incident ray. In Fig. 6.14, PO is the incident ray.

(*v*) **Reflected ray:** The ray of light which is sent back by the reflecting surface from the point of incidence, is called the reflected ray. In Fig. 6.14, OQ is the reflected ray.

(*vi*) **Angle of incidence:** The angle which the incident ray makes with the normal at the point of incidence is called the angle of incidence.

It is represented by the symbol $\angle i$. In Fig. 6.14, angle PON is the angle of incidence.

(*vii*) **Angle of reflection:** The angle which the reflected ray makes with the normal at the point of incidence is called the angle of reflection.

It is represented by the symbol $\angle r$. In Fig. 6.14, angle QON is the angle of reflection.

(*viii*) **Plane of incidence:** The plane in which the normal and the incident ray lie, is called the plane of incidence. In Fig. 6.14, the plane of the book-page, is the plane of incidence.

(*ix*) **Plane of reflection:** The plane in which the normal and the reflected ray lie, is called the plane of reflection. In Fig. 6.14, the plane of the book-page, is the plane of reflection.

6.16. MIRRORS

The polished surfaces used in the study of reflection of light, are called mirrors.

These are of two types: (*i*) *Plane mirrors* and (*ii*) *Spherical mirrors.*

(*i*) **Plane mirrors:** If the polished reflecting surface is plane, the mirror is called a plane mirror. Figure 6.15 shows, *XY* as the section of a plane mirror.

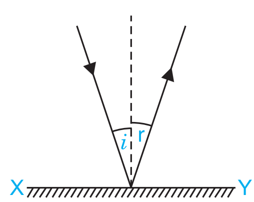


Fig. 6.15. Plane mirror.

(*ii*) **Spherical mirrors:** Spherical mirror is a part of a hollow sphere whose one side is polished.

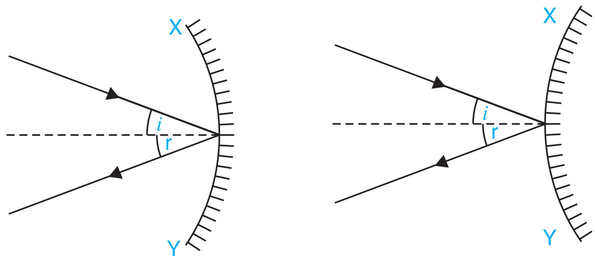
Spherical mirrors are of *two* types:

(*a*) *Concave mirror.* It is polished on the convex side and reflection from this mirror takes place from the concave side.

It is shown in Fig. 6.16 (*a*).

(*b*) *Convex mirror.* It is polished on the concave side and reflection from this mirror takes place from the convex side.

It is shown in Fig. 6.16 (*b*).



(a) Concave mirror (b) Convex mirror

Fig. 6.16. Spherical mirrors.

6.17. LAWS OF REFLECTION OF LIGHT

When light is incident on a smooth surface (mirror) then it gets reflected in accordance with the **two laws of reflection**. These laws of reflection are given below.

First law: *The incident ray, the reflected ray and the normal at the point of incidence, all lie in the same plane*. In Fig. 6.14, incident ray *PO*, reflected ray *OQ* and the normal *ON*, all lie in the same plane *i.e.*, plane of the paper.

Second law: The angle of incidence is always equal to the angle of reflection. If angle of incidence is $\angle i$ and angle of reflection is $\angle r$ then,

$$\angle i = \angle r$$

When a ray of light falls normally on a mirror *i.e.*, at right angle, then angle of incidence, $(\angle i) = 0°$. Since angle of incidence is 0°, hence in accordance with the second law of reflection, angle of reflection will also be zero *i.e.*, $\angle r = 0°$.

In other words, we can say that *when a ray of light falls normally on a mirror, then reflected ray will also travel perpendicular the mirror i.e., when a ray of light falls on a mirror normally, it gets reflected back along the same path.*

Laws of reflection given above are equally applicable to all types of mirrors.

6.18. REFLECTION FROM SPHERICAL MIRRORS

Some terms associated with spherical mirrors are given below:

(*i*) **Aperture:** *The diameter of the circular rim of the mirror is called the*

aperture of the mirror. *Size of the mirror is usually referred to as aperture*. In Fig. 6.17, *AB* is the aperture of the mirror.

(*ii*) **Pole:** *The centre of the spherical mirror is called* ***pole of the mirror***. It lies on the surface of the mirror. It is the lowest point in case of a concave mirror and highest point in case of a convex mirror. ***All distances are measured from the pole of the mirror*.** In Fig. 6.17, *P* is the pole of the mirror.

(*iii*) **Centre of curvature:** *Centre of curvature of a spherical mirror is the centre of the hollow sphere of which mirror is a part*. It lies outside the surface of the mirror. Every point on the surface of the spherical mirror lies at the same distance from it. In Fig. 6.17, *C* is the centre of curvature of the mirror.

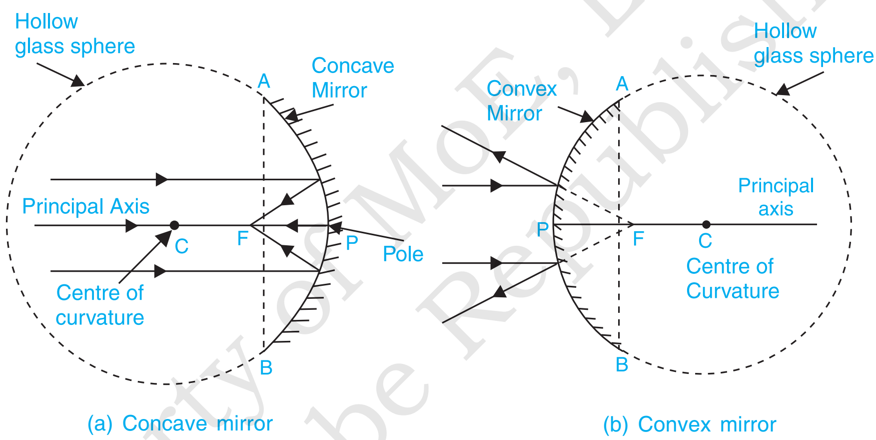


Fig. 6.17. Spherical mirrors.

(*iv*) **Principal axis:** *The straight line passing through the pole of the mirror and the centre of curvature of the mirror, is called principal axis of the mirror.*

(*v*) **Principal focus:** *It is a point on the principal axis of the mirror, such that the rays incident on the mirror, parallel to the principal axis, after reflection actually meet at this point (in case of a concave mirror) or appear to come from this point (in case of a convex mirror).* In Fig. 6.17, *F* is the principal focus of the mirror.

(*vi*) **Radius of curvature:** *The distance between the pole and the centre of curvature of the mirror is called the radius of curvature of the mirror*. It is equal to the radius of the hollow sphere of which, the mirror is a part. In Fig. 6.17, *PC* is the radius of curvature of the mirror. It is represented by the symbol *R*.

(*vii*) **Focal length:** *The distance between the pole and principal focus of the mirror is called the focal length of the mirror*. In Fig. 6.17, *PF* is the focal length of the mirror. It is represented by the symbol ***f***. For a **concave mirror focal length is negative**.

(*viii*) **Principal section:** *A section of the spherical mirror cut by a plane passing through its centre of curvature and the pole of the mirror, is called the* ***principal section of the mirror***. It contains the principal axis. In diagram, *APB* is the principal section of the mirror cut by the plane of the book page.

6.19 ELECTROMAGNETIC SPECTRUM (including elementary facts about their uses)

Electromagnetic waves cover a wide range of frequencies or wavelengths. The classification of electromagnetic waves does not have sharp boundaries. This is because the classification of electromagnetic waves is done according to their main source and different sources may produce waves in overlapping ranges of frequencies.

Electromagnetic spectrum *is the orderly distribution of electromagnetic radiations in accordance with their wavelength or frequency*. The usual classification of the electromagnetic spectrum is summarised below:

1. Radio frequency waves. (*a*) These have wavelengths ranging from a few kilometre down to 0.3 m. The frequency range is from a few Hz to 10^9 Hz.

(*b*) Radio waves reach us from **extraterrestrial sources.** The Sun is a major source of radio waves. These often interfere with radio and TV reception on Earth. Jupiter is also an active source of radio emissions.

(*c*) Mapping the radio transmissions from extraterrestrial sources, known as **radio astronomy,** has provided information about the universe that is often not obtainable using optical telescopes. Since the Earth's atmosphere does not absorb strongly at radio wavelengths, radio astronomy provides certain advantages over optical, infrared or microwave astronomy on Earth.

(*d*) *Properties of Radiowaves.* (*i*) They are electromagnetic waves. **(*ii*)** They travel with a velocity of 3×10^8 m s^{-1} in vacuum. **(*iii*)** They can be reflected, refracted and diffracted.

(*e*) *Uses of Radiowaves.* **(*i*)** The early uses were maritime, for sending telegraphic messages using Morse code between ships and land. **(*ii*)** They are used in AM broadcast radio and FM broadcast radio. **(*iii*)** They are used in Aviation voice radios and Marine voice radios. **(*iv*)** Civil and military voice services use short wave radio to contact ships at sea, aircraft and isolated settlements. **(*v*)** Radar detects things at a distance by bouncing radio waves off them. **(*vi*)** They are used in radio remote controls. **(*vii*)** They are used in radio and TV communication systems. **(*viii*)** They are used in radio-astronomy. **(*ix*)** Cellular phones use radio waves to transmit voice communication in the UHF band.

2. Microwaves. (short-wavelength radio waves) **(*a*)** The wavelengths of microwaves range from 0.3 m down to 10^{-3} m. The frequency range is from 10^{9} Hz upto 3×10^{11} Hz.The microwave region is also designated as UHF (ultra-high frequency relative to radio frequency).

(*b*) *Properties of Microwaves.* **(*i*)** They are electromagnetic waves. **(*ii*)** They travel with a velocity of 3×10^{8} m s^{-1} in vacuum. **(*iii*)** They can be reflected, refracted and diffracted. **(*iv*)** When absorbed by matter, they produce heat. **(*v*)** Microwaves pass easily through the earth's atmosphere with less interference than longer wavelengths. **(*vi*)** There is much more bandwidth in the microwave spectrum than in the rest of the radio spectrum. **(*vii*)** They can be used to transmit power over long distances.

(*c*) *Uses of Microwaves.* **(*i*)** They are used in the analysis of very fine details of atomic and molecular structure. **(*ii*)** They are used for cooking. Microwave ovens are an interesting domestic application of these waves. In such ovens, the frequency of the microwaves is selected to match the resonant frequency (3 GHz) of water molecules so that energy from the waves is transferred efficiently to the kinetic energy of the molecules. This raises the temperature of any food containing water. **(*iii*)** They are used in communication satellite transmissions. **(*iv*)** Due to their short wavelengths, they are suitable for the radar systems used in aircraft navigation. In fact, radar uses microwave radiation to detect the range, speed and other characteristics of remote objects. **(*v*)** Cable TV, Internet and cellphone networks make use of lower microwave frequencies.

3. Infrared rays. **(*a*)** The infrared spectrum covers wavelengths from 10^{-3} m down to 7.8×10^{-7} m (or 7800 Å). The frequency range is from 3×10^{11} Hz up to 4×10^{14} Hz.

(*b*) Infrared rays are produced by hot bodies and molecules. Broadly speaking, following are the laboratory sources for the **production** of infrared rays. The underlying principle is excitation of atoms and molecules. This may involve vibration and bending of molecules.

(*i*) *Laser.* It produces highly monochromatic infrared rays. CO_2 Laser gives infrared rays of wavelength 10.6 μm. He-Ne Laser gives infrared rays of wavelengths 0.69 μm, 1.19 μm and 3.39 μm.

(*ii*) *Filament of Nernst Lamp.* It is made from a mixture of zirconium, thorium and cesium. When current flows through such a filament, it gets heated. At a temperature of nearly 1200 K, infrared rays are emitted.

(*c*) *Earth as an infrared emitter.* The surface of earth absorbs visible radiation from the sun and re-emits a major portion of this energy as infrared back into the atmosphere.

(*d*) For **detection** of infrared rays, we use bolometers, thermopiles, photo conducting cells etc.

(*e*) Properties of infrared rays. (*i*) They are electromagnetic waves. **(*ii*)** They travel with a velocity of 3×10^8 m s^{-1} in vacuum. **(*iii*)** They show interference effects. **(*iv*)** They can be polarised. **(*v*)** They affect photographic plate. **(*vi*)** They show heating effect. **(*vii*)** Smoke is more transparent to infrared than to visible light. **(*viii*)** Under fog conditions, infrared can travel through long distances because of their low scattering.

(*f*) Uses of infrared rays. (*i*) They are used in night vision devices during warfare. This is because they can pass through haze, fog and mist. **(*ii*)** Infrared rays are used to take photographs in darkness. **(*iii*)** They are used to keep the green houses warm. **(*iv*)** They are used in revealing the secret writings on the ancient walls. **(*v*)** They are used in muscular therapy *i.e.,* to treat muscular strains. IR bulbs are used in muscular therapy. **(*vi*)** The infrared rays from the sun keep the earth warm. **(*vii*)** They provide electrical energy to a satellite by using solar cells. **(*viii*)** They are used in solar water heaters and cookers. **(*ix*)** They are used for producing dehydrated fruits. **(*x*)** They are used in weather forecasting through infrared photography.

4. Light or visible spectrum. This is a narrow band formed by the wavelengths to which our retina is sensitive. It extends from a wavelength of 7.8×10^{-7} m down to 3.8×10^{-7} m and frequencies from 4×10^{14} Hz up to 8×10^{14} Hz. Light is produced by atoms and molecules as a result of internal adjustment in the motion of their components, principally that of the electrons.

Colour	λ (in metre)	ν (in Hz)
Violet	$3.90 \times 10^{-7} - 4.55 \times 10^{-7}$	$7.69 \times 10^{14} - 6.59 \times 10^{14}$
Blue	$4.55 \times 10^{-7} - 4.92 \times 10^{-7}$	$6.59 \times 10^{14} - 6.10 \times 10^{14}$
Green	$4.92 \times 10^{-7} - 5.77 \times 10^{-7}$	$6.10 \times 10^{14} - 5.20 \times 10^{14}$
Yellow	$5.77 \times 10^{-7} - 5.97 \times 10^{-7}$	$5.20 \times 10^{14} - 5.03 \times 10^{14}$
Orange	$5.97 \times 10^{-7} - 6.22 \times 10^{-7}$	$5.03 \times 10^{14} - 4.82 \times 10^{14}$
Red	$6.22 \times 10^{-7} - 7.80 \times 10^{-7}$	$4.82 \times 10^{14} - 3.84 \times 10^{14}$

The sensitivity of the eye also depends on the wavelength of light. This sensitivity is maximum for wavelengths of approximately 5.6×10^{-7} m. Because of the relation between colour and wavelength or frequency, an electromagnetic wave of well-defined wavelength or frequency is also called a monochromatic wave (monos-one ; chromos colour).

5. Ultraviolet Rays. (*a*) These rays were discovered by Ritter in 1801.

Ultraviolet rays are electromagnetic waves whose wavelength ranges from 6×10^{-10} m (0.6 nm) to 4×10^{-7} m (400 nm). The frequency ranges from 8×10^{14} Hz to 5×10^{17} Hz.

Their energy is of the order of magnitude of the energy involved in many chemical reactions. This accounts for many of their chemical effects.

(b) Ultraviolet rays are a part of the solar spectrum. These waves are produced by atoms and molecules in electrical discharges. They can be produced by passing discharge through hydrogen and xenon. They can also be produced by the arcs of mercury and iron.

The sun is a very powerful source of ultraviolet radiation. This fact is mainly responsible for suntans. Exposure to UV radiation induces the production of more melanin, causing tanning of the skin. UV radiation is absorbed by ordinary glass. Hence, one cannot get tan or sunburn through glass window.

Welders wear special glass goggles or face masks with glass windows to protect their eyes from large amount of UV produced by welding arcs.

(*c*) *Properties of ultraviolet rays.* **(*i*)** They are electromagnetic waves. **(*ii*)** They travel with a velocity of 3×10^8 m s^{-1} in vacuum. **(*iii*)** They obey the laws of reflection and refraction. **(*iv*)** They show interference and polarisation. **(*v*)** They affect photographic plate. **(*vi*)** They show photoelectric effect. **(*vii*)** They cannot pass through glass. However, they can pass through quartz, fluorite and rock salt. **(*viii*)** They can cause fluorescence in certain materials. **(*ix*)** When skin is exposed to sunlight, ultraviolet rays synthesise vitamin D. **(*x*)** These rays are very harmful to the living tissues. **(*xi*)** Brief exposure to ultraviolet radiation causes common sunburn, but long-term exposure can lead to more serious effects, including skin cancer.

(*d*) *Uses of ultraviolet rays.* **(*i*)** They are used to preserve food stuffs as the rays kill germs. **(*ii*)** They are used to make drinking water free from bacteria. UV lamps are used to kill germs in water-purifiers. **(*iii*)** Ultraviolet absorption spectra are used in the study of molecular structure and the arrangement of electrons in the external shells of atoms. **(*iv*)** Ultraviolet rays have medical applications. Since these rays destroy bacteria therefore they are used for sterilising surgical instruments. **(*v*)** They are used in detecting the invisible writings, forged documents, counterfeit currency notes and finger prints in forensic laboratory. **(*vi*)** Ultraviolet rays are used for checking the mineral samples by making use of the fact that ultraviolet rays cause fluorescence.

6. X-rays. This part of the electromagnetic spectrum extends from wavelengths of nearly 10^{-9} m down to wavelengths of nearly 6×10^{-12} m or frequencies between 3×10^{17} Hz and 5×10^{19} Hz. X-rays were discovered in 1895 by the German physicist W. Roentgen when he was studying cathode rays. **X-rays are produced** by the inner or more tightly bound electrons in atoms. Another source of X-rays is the *bremsstrahlung* or decelerating radiation.

They are **used** in medical diagnosis because the relatively greater absorption of X-rays by bone as compared with tissue allows for a fairly well-defined pattern on a photographic film. They also, as a result of the chemical processes they induce, cause serious damage to living tissues and organisms. It is for this reason that X-rays are used for treatment of cancer, to destroy diseased tissue. It should be emphasised that even a small amount of X-rays also destroys some good tissue and exposure to a large dose of X-rays may cause enough destruction to produce sickness or death.

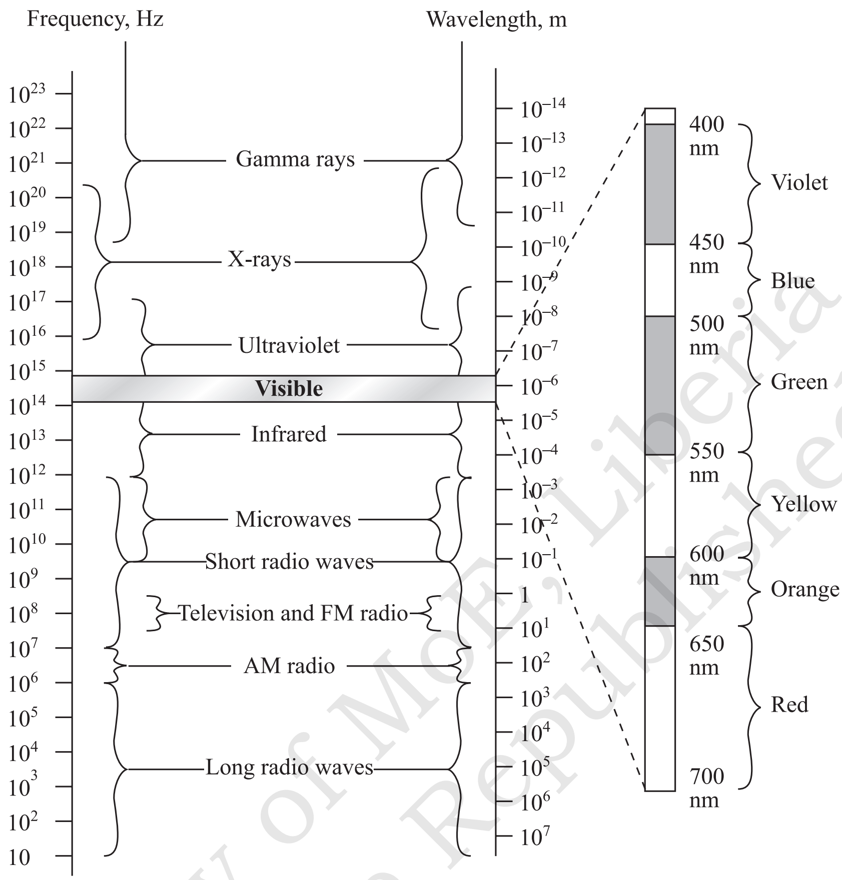


Fig. 6.18. The electromagnetic spectrum, with common names for various part of it. The various regions do not have sharply defined boundaries.

7. Gamma rays. These electromagnetic waves are of nuclear origin. They overlap the upper limit of the X-ray spectrum. Their wavelength ranges from nearly 10^{-10} m to well below 10^{-14} m, with a corresponding frequency range from 3×10^{18} Hz to more than 3×10^{22} Hz. The energies of these waves are of the same order of magnitude as those involved in nuclear processes and therefore the absorption of γ-rays may produce some nuclear changes. **Gamma rays are produced** by many radioactive substances and are present in large quantities in nuclear reactors.

Uses of Gamma Rays : Gamma rays are used:

(*i*) in radiotherapy for the treatment of malignant tumours.

(*ii*) to initiate some nuclear reactions.

(*iii*) to preserve food stuffs for a long time. This is because soft γ-rays can kill micro-organisms.

(*iv*) to study the structure of atomic nuclei.

REVIEW EXERCISES

Do the review exercises in your notebook.

A. Multiple Choice Questions

1. The energy whose presence makes the surrounding objects visible is:
(a) heat (*b*) sound
(*c*) light (*d*) electrical.

2. Medium through which light is fully passed, is called
(a) transparent (*b*) opaque
(*c*) transluscent (*d*) alloy.

3. Medium through which light cannot pass, is called
(a) transparent (*b*) opaque
(*c*) transluscent (*d*) alloy.

4. Medium through which light is partially passed, is called
(a) transparent (*b*) opaque
(*c*) transluscent (*d*) opaque transparent.

5. Angle of reflection is the angle between
(a) incident ray and normal to the surface
(*b*) incident ray and surface of the mirror
(*c*) reflected ray and surface of mirror
(*d*) reflected ray and normal to the surface.

6. In case of reflection from a spherical mirror, the image formed is
(*a*) always real
(*b*) always virtual
(*c*) real as well as virtual
(*d*) neither real nor virtual.

7. In sign convention to be followed, the mirror is kept with its reflecting face towards
(*a*) left (*b*) right
(*c*) upward (*d*) downward.

8. Image of the face has an enlarged size when seen in a mirror from a close distance. The mirror is
(a) plane (b) concave
(c) convex (d) parabolic

9. Bending of a ray of light, when it enters obliquely from one medim to other is called
   (a) reflection (b) refraction
   (c) dispersion (d) interference
10. The relation, $\frac{\sin i}{\sin r} = n$, is called
   (a) Snell's law (b) Newton's law
   (c) Joule's law (d) Boyle's law

B. Fill in the Blanks

1. __________ nature of light is used in our everyday life.
2. Light passes partially through __________ medium.
3. When two converging rays become incident on a convex mirror, the image formed is __________ .
4. Height of an inverted real image has a __________ sign.
5. For a convex mirror, magnification m is __________ one.
6. In refraction, a ray of light __________ when it enters obliquely in some other medium.
7. Image distance for the image on the right of the lens is __________ .
8. A lens is put over a printed page, if diminished image of the print is seen, then lens is __________ .
9. A ray of light passing through the optical centre of a lens goes __________.
10. If ${}^a n_g = 3/2$, then ${}^g n_a =$ __________ .

C. Very Short Answer Questions

1. Which is a converging mirror: a convex or a concave?
2. Can a magnified image be formed by a convex mirror?
3. What determines the focal length of a spherical mirror?
4. In a concave mirror, is the reflecting surface away from the centre of the sphere of which the mirror forms a part?
5. In a concave mirror, when is the size of image exactly equal to the size of the object?
6. What is the angle of incidence when a ray falls normally on a mirror?
7. Do the laws of reflection hold good in case of spherical mirrors?
8. What is meant by refraction of light?
9. What do you mean by an optical medium?
10. What is the approximate wavelength of X-rays?

D. Short Answer Questions

1. What is a mirror formula? Is it same for a convex and concave mirrors?
2. What is the focal length of a plane mirror?
3. A ray of light falls on a plane mirror making an angle of 60° with the mirror. Find the angle through which the ray gets deviated after reflection from the mirror.
4. An object is held at 30 cm in front of a convex mirror of focal length 15 cm. At what distance from the convex mirror should a plane mirror be held so that images in the two mirrors coincide with each other?
5. What is mirror formula? Does it change with the nature of the image formed? Express the mirror formula in terms of radius of curvature of the mirror.

E. Long Answer Questions

1. An erect image three times the size of the object is obtained with a concave mirror of radius of curvature 0.36 m. Find the position of the object.
2. The image formed by a convex mirror of radius of curvature 40 cm is a quarter of the object. Calculate the distance of the object from the mirror.
3. When an object is placed at a distance of 60 cm from a convex mirror, the magnification produced is 1/2. Where should the object be kept to get a magnification of $\frac{1}{3}$.
4. A concave lens of focal length 25 cm and a convex lens of focal length 20 cm are placed in contact with eachother. What is the power of this combination? Also, calculate focal length of the combination.
5. A concave lens has focal length of 15 cm. At what distance should an object from the lens be placed so that it forms an image at 10 cm from the lens? Also, find the magnification of the lens.